Water Research 83 (2015) 94–103

Contents lists available at ScienceDirect

Water Research

journal homepage: www.elsevier.com/locate/watres

Water quality as a predictor of gastrointestinal illness following incidental contact water recreation

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ARTICLE INFO

Article history:
Received 20 December 2014
Received in revised form
4 June 2015
Accepted 17 June 2015
Available online 21 June 2015

Keywords:
Water recreation
Gastrointestinal illness
Epidemiology
Incidental contact
Fecal indicator bacteria

ABSTRACT

Microbial measures of water quality are predictors of gastrointestinal illness among swimmers in some settings but not in others. Little is known whether water quality measures predict illness among people who engage in popular water recreation activities such as paddling, rowing, fishing, or boating ("incidental contact water recreation"). We sought to evaluate indicator microbes, protozoan pathogens, and turbidity as predictors of gastrointestinal illness following incidental contact water recreation. A cohort study of incidental contact water recreation was conducted in the Chicago, USA area. Recreation took place on inland lakes, rivers, Lake Michigan, and an urban waterway heavily impacted by wastewater effluent. Water samples were analyzed for *Escherichia coli*, enterococci, somatic coliphages, F+ coliphages, *Giardia* spp. and *Cryptosporidium* spp. (oo)cysts, and for turbidity. Median enterococci concentrations were 71.0 and 199.8 colony forming units/100 mL at general use and effluent-dominated waters, respectively. Among 4694 study participants with complete covariate data, 193 (4.1%) developed gastrointestinal illness within three days of water recreation. In multivariable logistic regression analysis, water quality metrics did not predict gastrointestinal illness among water recreators. Several variables other than water quality were associated acute gastrointestinal illness. The odds of such illness was increased by approximately two-fold by the presence of a chronic gastrointestinal condition, water exposure to the face, and by approximately 50% among those who fished (as opposed to other incidental contact activities). The odds of illness were reduced by approximately 50% among individuals who frequently used a water body for recreation. Unlike studies of swimmers at wastewater-impacted beaches that observed associations between water quality and illness incidence, this study did not. Public health protections for incidental contact recreation might focus on reducing exposure, particularly among fishers, those with chronic gastrointestinal conditions, and new recreators.

1. Introduction

Epidemiologic studies of water recreation have consistently found that swimmers develop gastrointestinal illness more frequently than non-swimmers at freshwater (Wade et al., 2008, 2006), marine (Arnold et al., 2013; Colford et al., 2007; Wade et al., 2010) and riverine (Ferley et al., 1989) beaches. Controlled exposure studies, in which participants were randomly assigned to either remain on the beach (avoiding water contact) or to perform head immersion in beach water, have also consistently found that water-exposed individuals are more likely to develop gastrointestinal illness than the unexposed (Fleisher et al., 2010; Kay et al., 1994; Wiedenmann et al., 2006).

Less consistent are findings of studies that have used microbial measures of water quality to predict the occurrence of illness. For example, at two California beaches, swimmers were more likely than non-swimmers to develop illness, but among swimmers, densities of fecal indicator bacteria measured by culture or quantitative polymerase chain reaction (qPCR) were not predictive of gastrointestinal illness occurrence (Arnold et al., 2013; Colford et al., 2007). Likewise, a controlled exposure study set in Florida found that water-exposed individuals were more likely to develop illness than unexposed individuals (Fleisher et al., 2010), though within the water-exposed group, no association was observed

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http://dx.doi.org/10.1016/j.watres.2015.06.028
0043-1354/

between gastrointestinal symptoms and enterococci (measured by culture and qPCR) or Bacteroidales (measured by qPCR) (Sinigalliano et al., 2010).

Studies of the health risks of swimming have utilized "fecal indicator bacteria" (FIB), microbes that indicate the presence of fecal contamination, including *Escherichia coli* and/or enterococci, as predictors of illness. Although pathogens – microbes that cause illness in humans – can be measured in surface water, few epidemiologic studies of water recreation have included pathogen measurements, in part because they are difficult and costly to perform. Adenovirus, enterovirus, and norovirus were evaluated as predictors of illness among swimmers at Mission Bay, CA (Colford et al., 2007), though pathogen detection was infrequent and not predictive of illness. Coliphages, viruses that infect *E. coli*, have shown some promise as predictors of illness among individuals randomized to water exposure (head immersion) in inland waters (Wiedenmann et al., 2006), among swimmers in relatively clean marine water (Colford et al., 2007), and among users of a white-water slalom course fed in part by treated wastewater (Lee et al., 1997).

Epidemiologic studies that evaluated water quality as a predictor of short-term health risks following water recreation have generally addressed swimming (or "full contact water recreation"), while only a few relatively small studies have addressed incidental contact water recreation, such as canoeing, kayaking, fishing, rowing, or boating (Fewtrell et al., 1992; Lee et al., 1997). As a result, while incidental contact water recreation is popular and takes place on some waters where swimming is prohibited, water quality standards that safely support such recreation have yet to be established nationally in the US. We previously reported that in the Chicago Health, Environmental Exposure, and Recreation Study (CHEERS), users of Chicago area surface waters for incidental contact water recreation activities were at risk for developing acute gastrointestinal illness (AGI). Participants used either the engineered Chicago Area Waterways System, which includes the Chicago River and is predominantly treated, but non-disinfected wastewater effluent, or general use waters that could support full-contact water recreation. The risk of AGI attributable to incidental contact recreation was 13.7 (95% confidence interval 3.1, 27.4) and 15.1 (2.6, 25.7) per 1000 uses at effluent dominated and general use locations, respectively (Dorevitch et al., 2012b). The primary objective of the present study is to evaluate microbial measures of water quality, including coliphages and the protozoan pathogens *Giardia* spp. and *Cryptosporidium* spp., as predictors of gastrointestinal illness occurrence among incidental contact water recreators.

2. Materials and methods

2.1. Overview

Prior publications provide details about the setting, short-term health risks of incidental contact water recreation (Dorevitch et al., 2012b), estimated volume of water swallowed during water recreation (Dorevitch et al., 2011b), pathogens detected in stool samples from CHEERS participants who developed gastrointestinal symptoms (Dorevitch et al., 2012a), and measures of viral (Aslan et al., 2011) and protozoan (Dorevitch et al., 2011a) pathogens in the waters studied. Briefly, incidental contact water recreators as well as individuals who engaged in non-water recreation (such as jogging, cycling, walking, and team sports) were recruited at boat launches, harbors, piers, and beaches in the Chicago area. Data collection methods, including survey instruments, were based on the US Environmental Protection Agency's National Environmental and Epidemiologic Assessment of Recreational water (NEEAR) study (Wade et al., 2008, 2006, 2010). Participants underwent a pre-recreation interview to establish eligibility, and a post-recreation interview to evaluate water exposure during recreation as well as other risk factors for illness. Water exposure was assessed by asking participants a series of questions about swallowing water as well as head/face, and trunk exposure. Ordinal response options included none, a few drops, splashed, drenched, or submerged. These response options were validated as being associated with varying degrees of water exposure using a chemical tracer in a swimming pool (Dorevitch et al., 2011b). Participants were interviewed by telephone on approximately days 2, 5, and 21 post-recreation to evaluate the occurrence of symptoms. For their time and effort participants received a T-shirt and a $15 gift card upon completion of the post-recreation interview (in the field). At the completion of telephone follow-up each was sent a check for $35. Follow-up data were available from 11,297 individuals, or 94.5% of the 11,733 who completed the field interviews and did not have gastrointestinal symptoms at baseline. In the present analysis, we focus on the 7710 study participants who engaged in incidental contact water recreation on either the effluent-dominated or the general use waters.

Definition of illness: AGI was defined as the occurrence of 1) any vomiting and/or 2) at least three loose stools in a 24 h period, and/or 3) nausea or stomachache that interfere with daily activity, or 4) nausea with stomach ache, consistent with the NEEAR definition of AGI (Wade et al., 2008, 2006, 2010). Based on Kaplan–Meier analysis of illness onset among CHEERS participants (Dorevitch et al., 2012b), AGI was defined as the occurrence of these symptoms during the three days following enrollment (rather than the 10–12 day period used in NEEAR). The 0–3 day window was selected because since the publication of NEEAR findings, it has become clear from Kaplan–Meier analyses of CHEERS data (Dorevitch et al., 2012b) as well as other cohort studies conducted at California beaches (Arnold et al., 2013; Colford et al., 2012) that the difference between water recreators and non-water recreators in the rate of new onset AGI symptoms is greatest during that brief, initial time period following water recreation. Individuals with any gastrointestinal symptoms when starting water recreation were excluded from analyses of AGI.

2.2. Water sample analysis

Grab samples of surface water (<10 cm from the surface) were collected every two hours during water recreation using a telescoping pole from boat launches and piers at locations where recreation began and ended. Recreation and recruitment took place at 1–4 recreational areas per study day, and water sampling locations at each recreational area were constant throughout the duration of the study. Grab samples were for analysis of *E. coli*, enterococci, somatic coliphage, F+ coliphage, and turbidity. Twenty liter samples were collected approximately every 6 h for protozoan (oo)cyst analysis. Grab samples were analyzed by membrane filtration for *E. coli* (EPA Method 1603) and enterococci (EPA Method 1600) using five different dilutions per sample. Culture results used in data analyses were those from the dilution that produced approximately 20–60 colony forming units (CFU) per plate (USEPA R&D, 1978). These analyses were performed by certified commercial laboratories. Scientific Methods, Inc. (Granger, IN) analyzed somatic and F+ coliphage analyses by EPA Method 1602, and Giardia *spp*. and *Cryptosporidium* spp. (oo)cyst analyses by EPA Method 1623 following continuous flow centrifugation of 20 L samples as described previously (Dorevitch et al., 2011a). Turbidity was measured on site using HF Scientific MicroTPW portable turbidimeters. Quality assurance measures included the use of blinded field blanks, replicate samples, and spiked samples. Participants